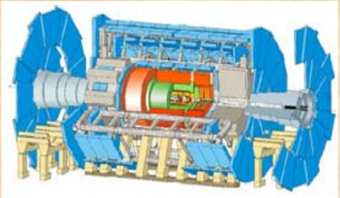


Other BSM Searches at the LHC

Kamal Benslama

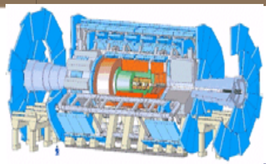
University of Regina

On behalf of the ATLAS and CMS Collaborations

November 18, 2009

Hadron Collider Symposium

Evian, France



BSM Scenarios

SUSY
New particles at TeV scale

Extra Dimensions
Additional dimensions
New state at TeV Scale

$$\frac{M_{EW}}{M_{Plank}} \sim 10^{-17}$$

$$\delta m_M \sim \Lambda$$

→ New Physics at TeV Scale to stabilize m_H

Little Higgs
SM embedded in larger group
New particle at TeV scale

Technicolor
-New strong interactions break EW symmetry
-New particles at TeV scale

- Other Scenarios of New Physics
  - Leptoquarks
  - Exicted fermions
  - New gauge bosons

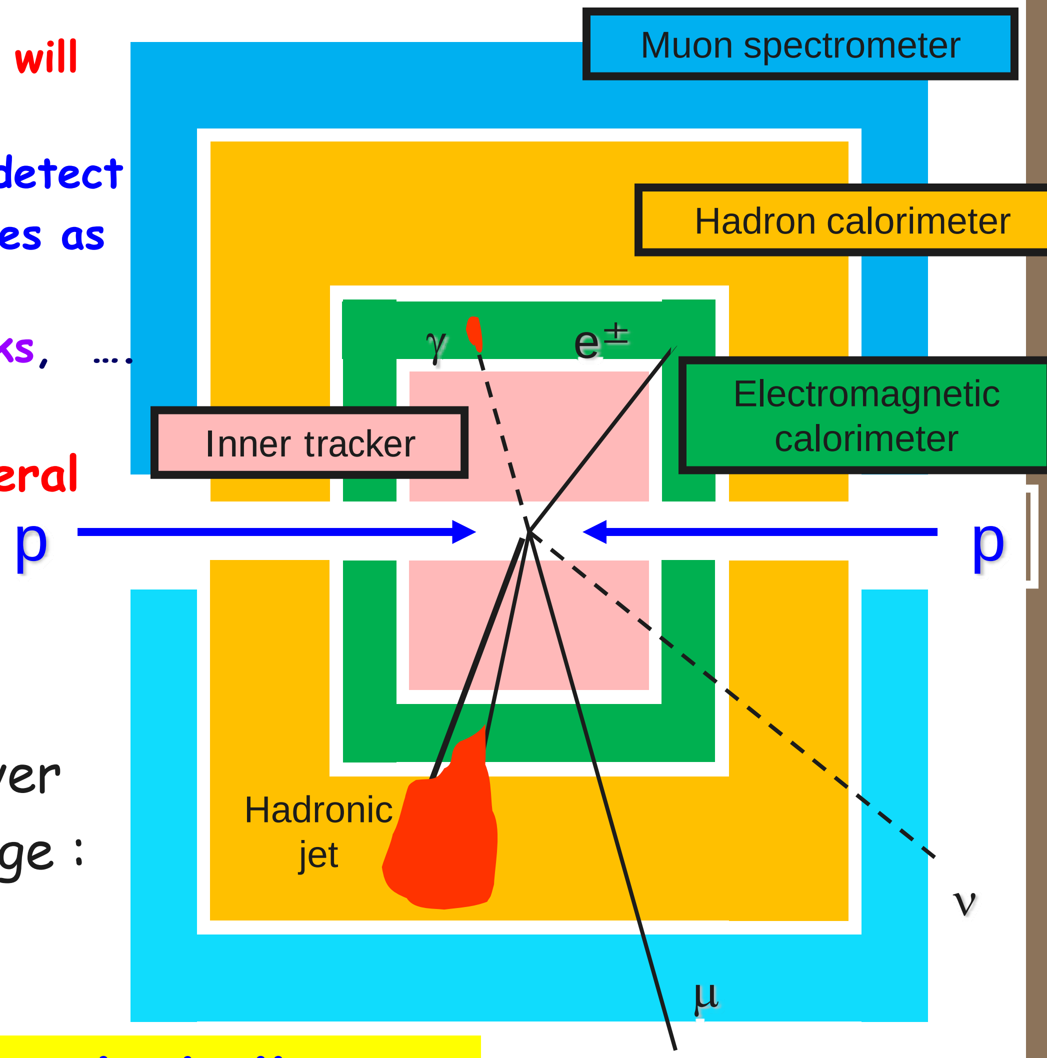
Search for New Physics

Don't know how New Physics will manifest itself

→ detectors must be able to detect as many particles and signatures as possible:

e, μ, τ, ν, γ, jets, b-quarks, ….

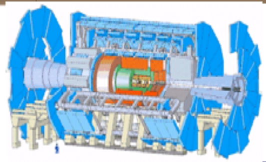
→ ATLAS and CMS are general purpose experiments.



Excellent performance over unprecedented energy range :

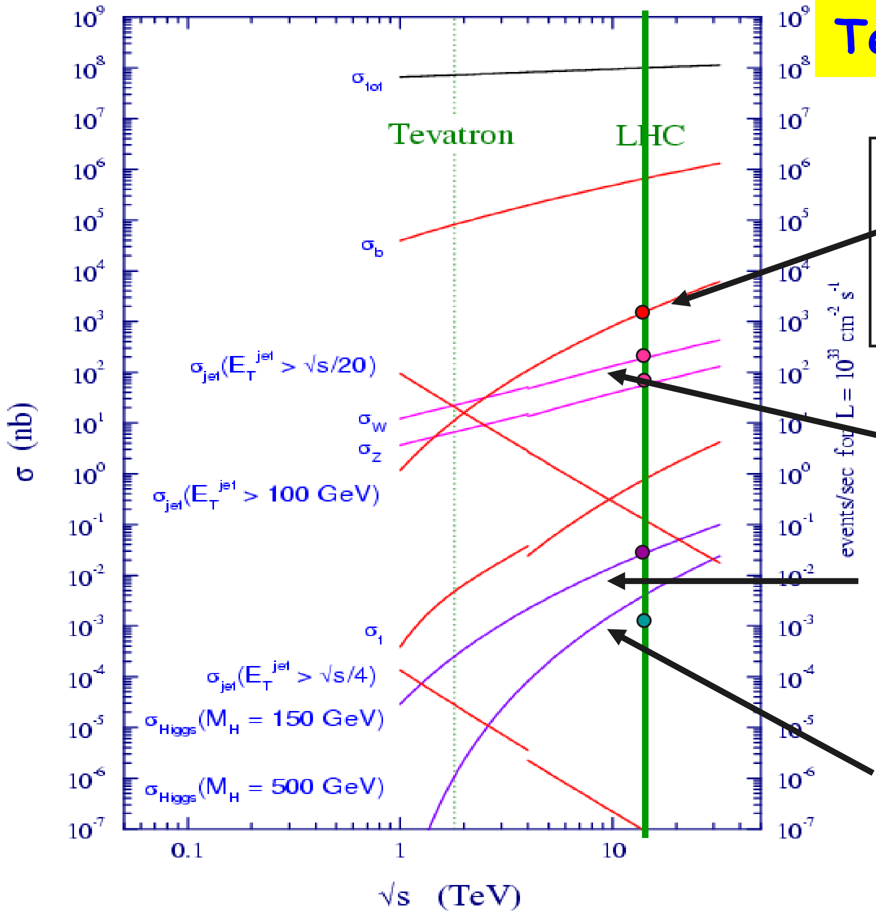
few GeV → few TeV

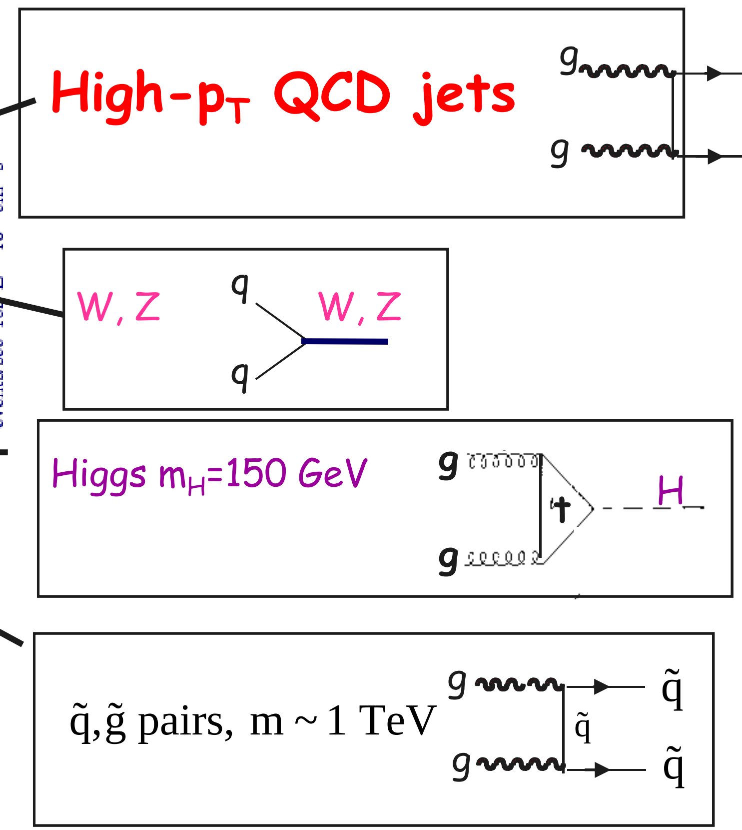
Experimental Challenges



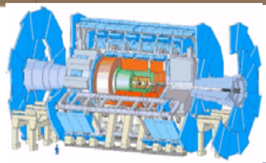
Experimental Challenges: QCD Background

e/jet (p_T>20 GeV) ~ 10^{-3} (10^{-5}) at Tevatron (LHC)





Extraction of tiny signals from backgrounds: excellent identification



New Physics: Real life…

l+jets+$\not\!\!E_T$

ll+jets+$\not\!\!E_T$

jets+$\not\!\!E_T$

bb+γ

taus+$\not\!\!E_T$

ll

bb+$\not\!\!E_T$

Massive Stable Particle

ll+bb+$\not\!\!E_T$

ll +jets

γ+jets+$\not\!\!E_T$

l+ $\not\!\!E_T$

$llll$+$\not\!\!E_T$

Kinks

monojets

γ+ll+$\not\!\!E_T$

lll+jets+$\not\!\!E_T$

Non-prompt photons

or Z's

$\gamma\gamma$+E_T

It's a complicated environment

In this talk, I will focus on earliest analyses with ~ 100 pb^{-1} @ 14 TeV:

- Dileptons
- Leptons + MET
- Leptons + Jets

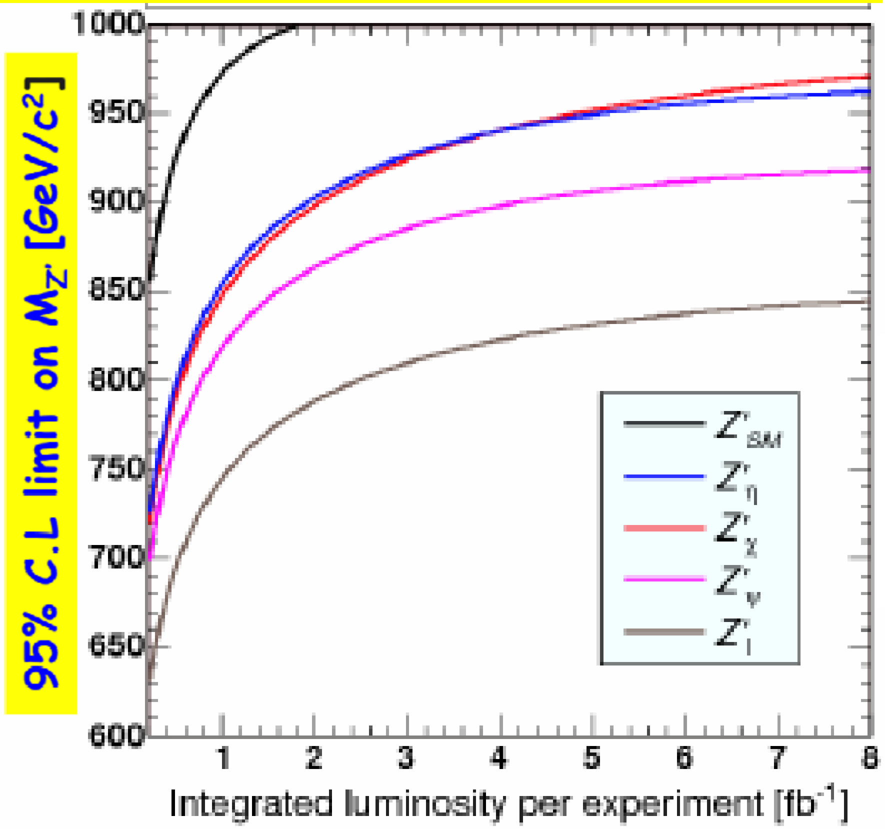
I will comment and compare with results obtained @ 10 TeV

@10 TeV: cross sections are ~50-75% smaller in 100 GeV to 1 TeV

References are given in the last slide

Dileptons

Tevatron projections for Z' to ee



Tevatron limited by CM energy

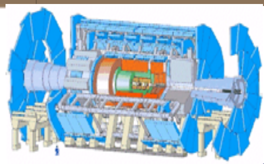
At the LHC (CM = 14 TeV)

For a Z' with
SM –like coupling

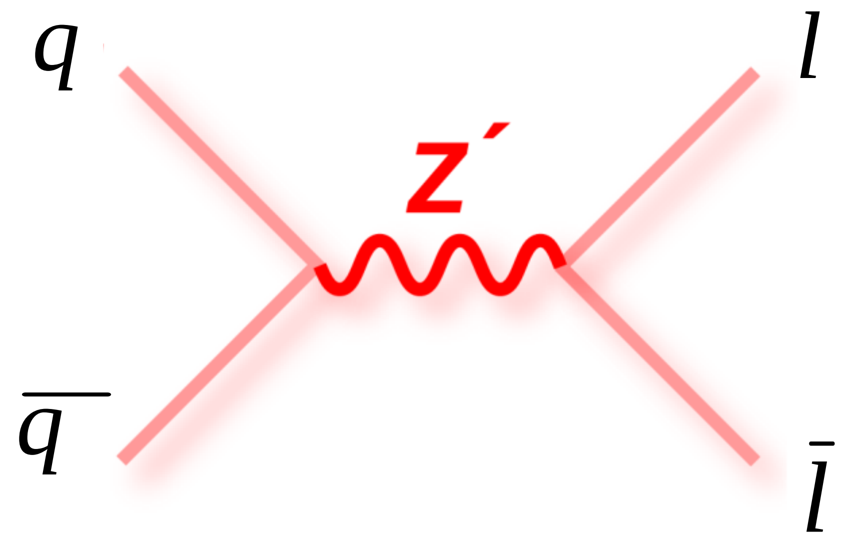
$\sigma(pp \to Z' \to ll) \sim 0.5$ pb (M(Z')=1 TeV)

@10 TeV

Production cross sections are reduced by factors ~ 2 or 3 (for masses of the Z' between 1 and 2 TeV)



Di-leptons: Z'

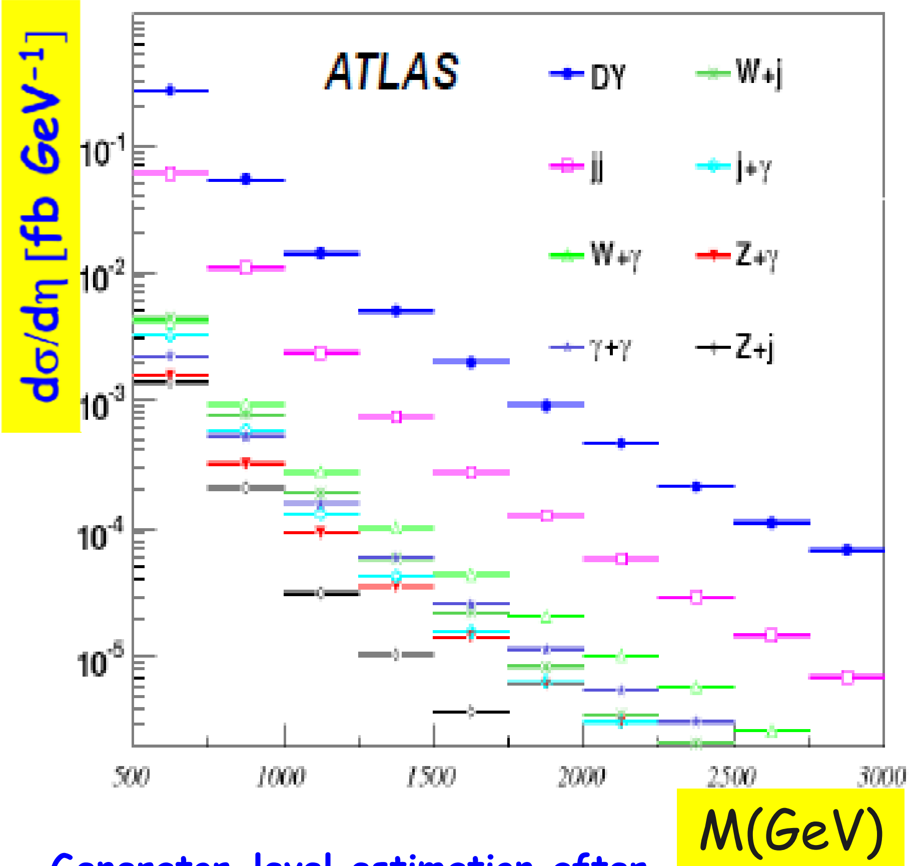


Signature Selection:

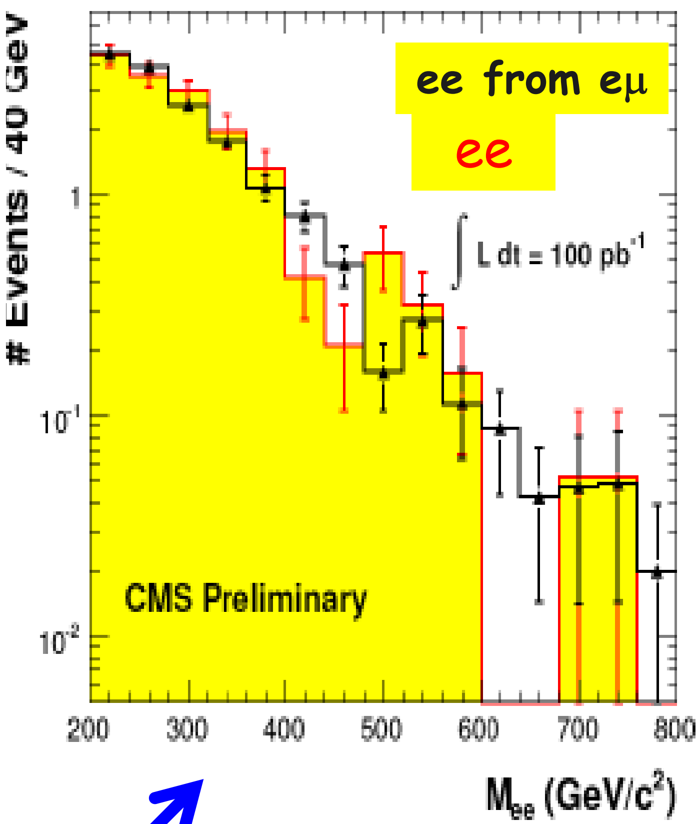
-Relatively clean signatures
-Good mass resolution
-Easy to trigger on

-2 well reconstructed, isolated leptons
- |eta|<2.5 (except muons in CMS, 2.4)
- pT>30 or 50 GeV

Backgrounds



Generator-level estimation after Applying current values of jet and photon Rejection (10^4 and 10, respectively)

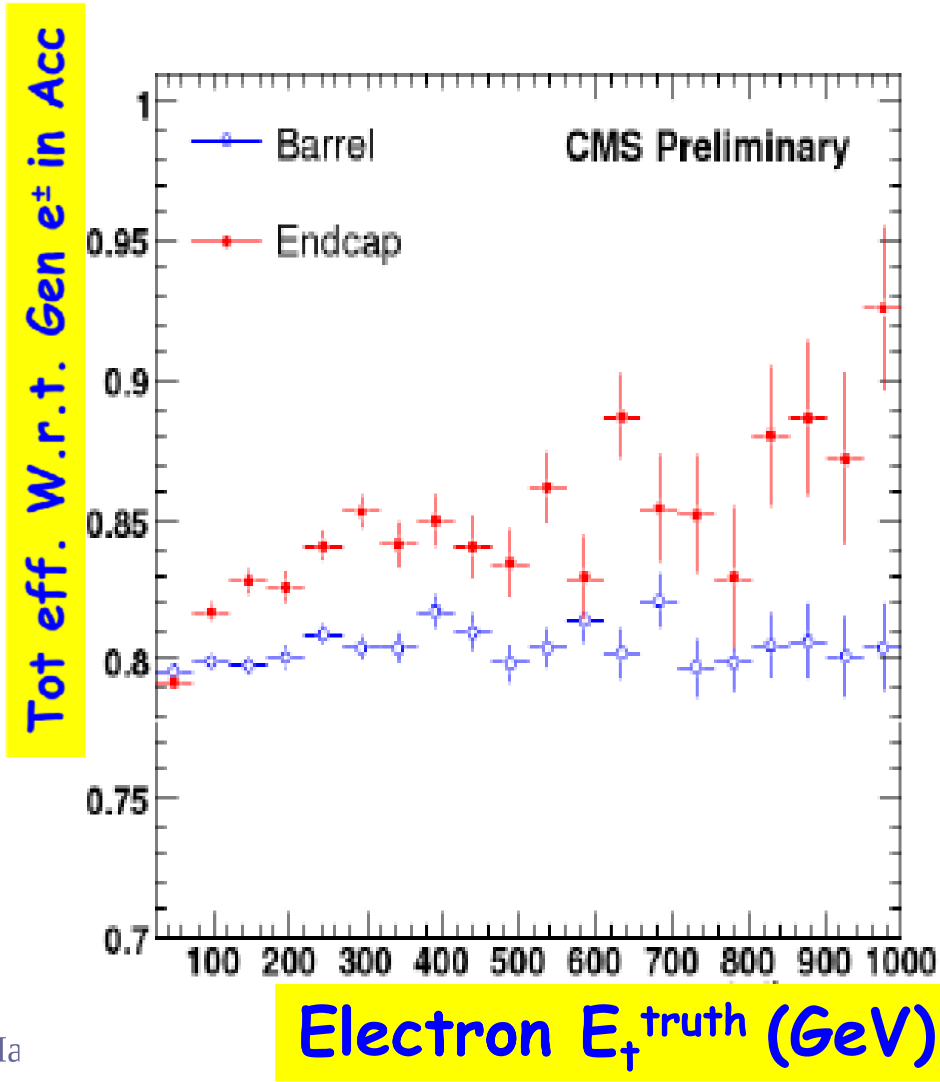


Data driven ttbar to ee background estimation
count the ttbar to eμ (CMS)
$N_{\mu e} \sim 2\ N_{ee}$

High Energy Electron Reconstruction and ID optimization

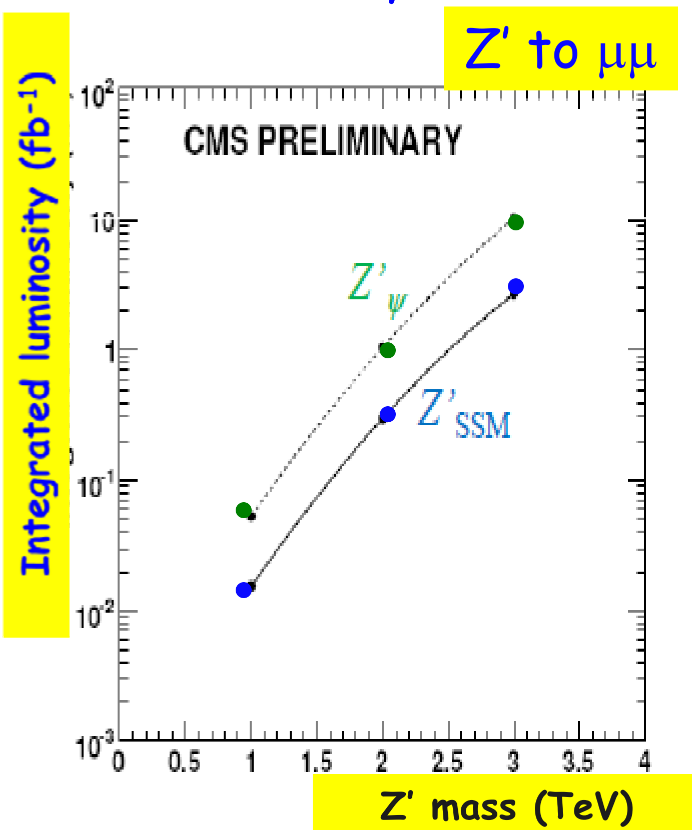
- Robust selection criteria based on shower shape, track matching, isolation
  - Efficiency ~ 80%
  - Jet rejection ~ 4×10^{-5}

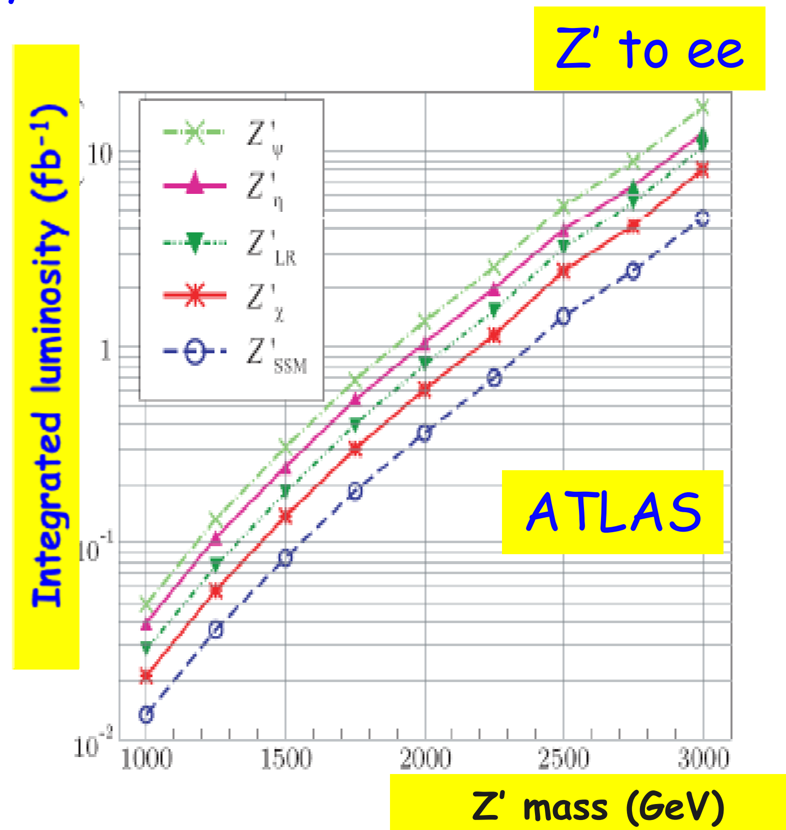
- ECal saturation (CMS):
  - large energy deposit in one crystal
  - can be recovered using surrounding crystals



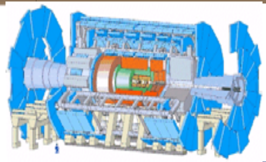
Z' Sensitivity, Reach

- Comparable reach for both experiments
- If slightly above the current Tevatron limit (1 TeV), as low as 100 pb^{-1} of well understood data could yield a 5σ discovery



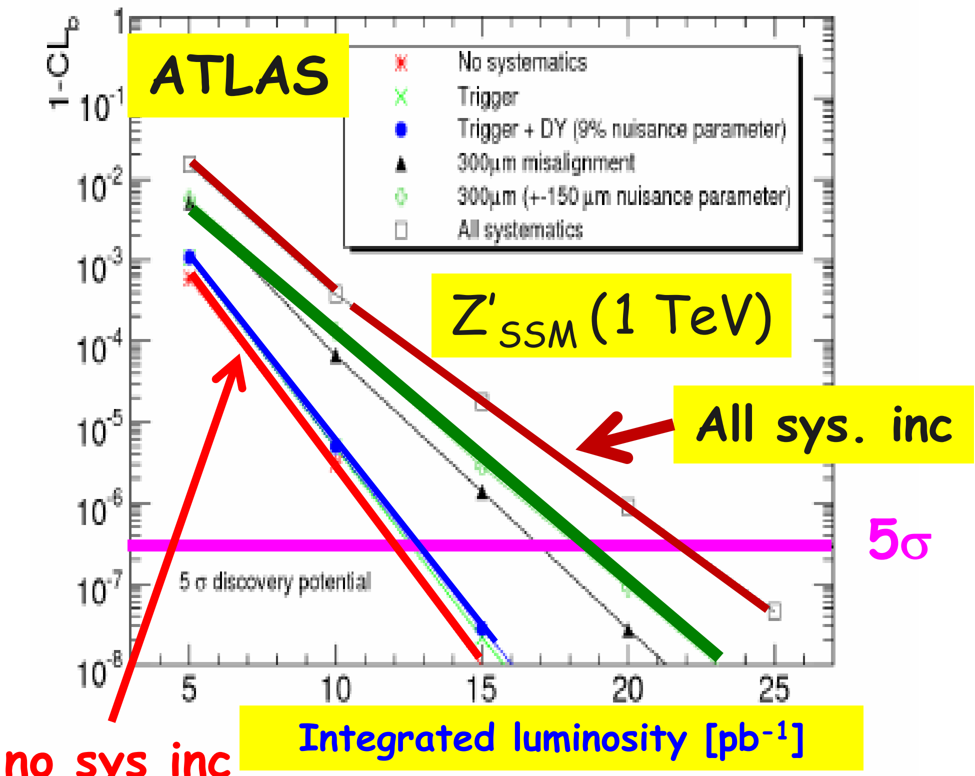


Background: Drell-Yan 1% signal (QCD reduced to 0.3 DY)
Atlas mass resolution ~1% increased to 1.5% → 5% syst. error
CMS mass resolution ~2% assuming calibration available with 100 pb^{-1}
Theoretical uncertainties →10%



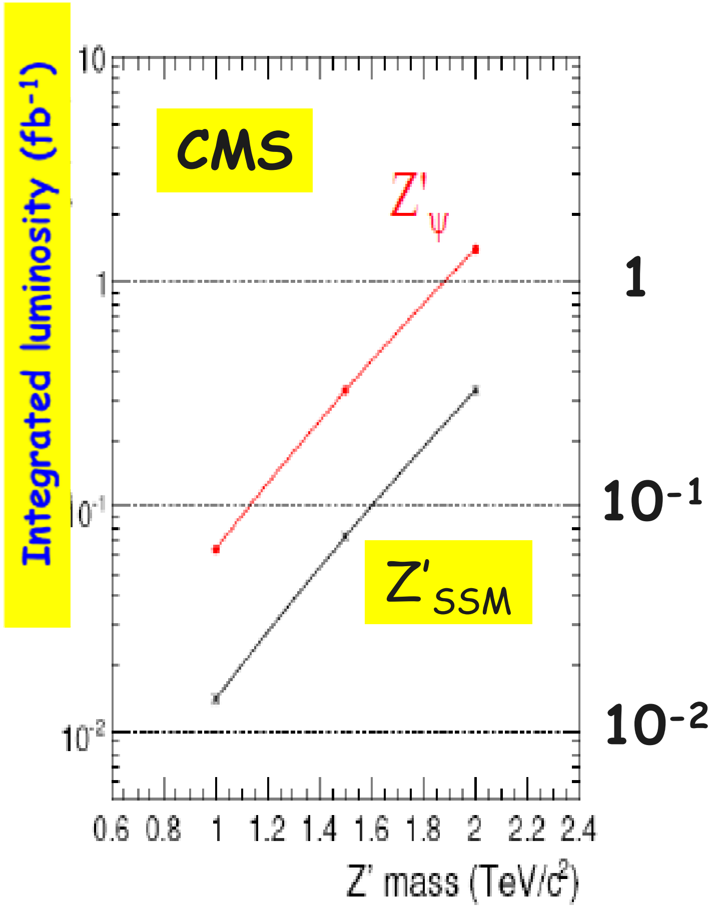
Z' to μμ

- Competitive with electron channel (even if lower resolution)
- Discovery possible with less than **30 pb^{-1}**



Trigger +DY

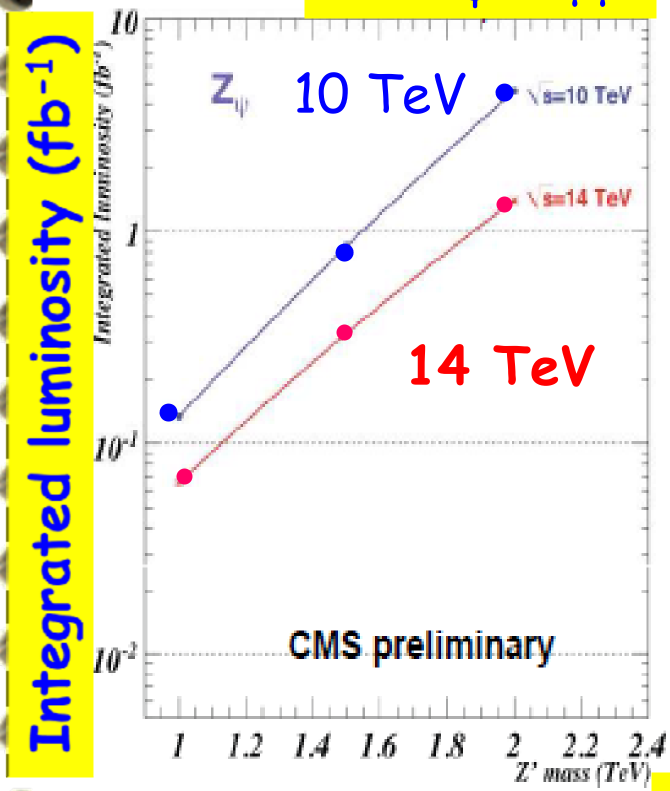
misalignment scenario



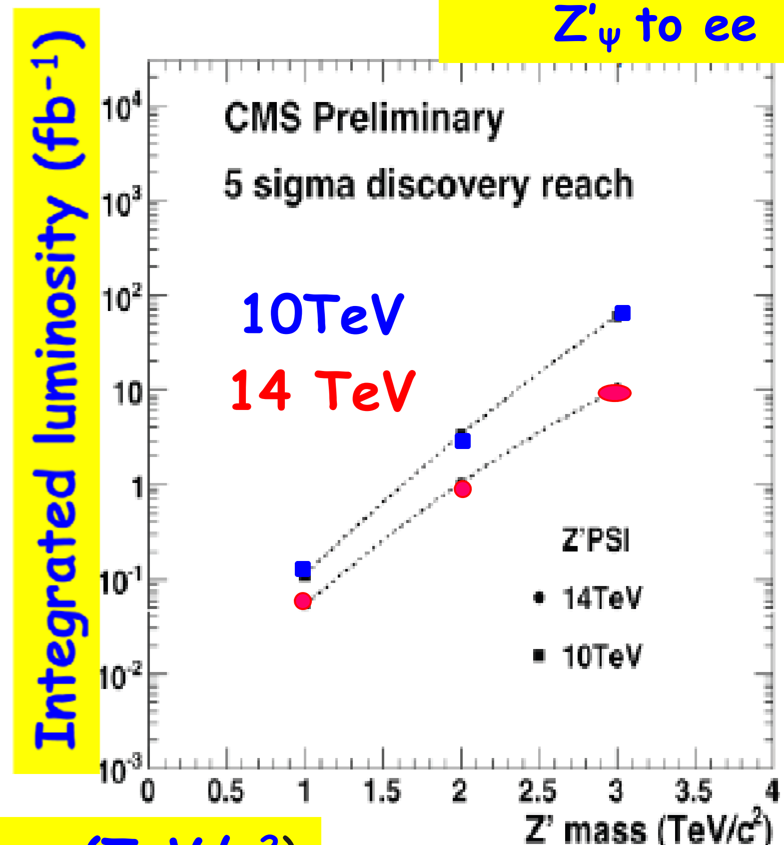
How about 10 TeV?

- Production cross section: reduced by a factor 2 to 3 for 1TeV<$M_{Z'}$<2TeV
- Luminosity for 5σ discovery ~ doubles

Z'_ψ to μμ



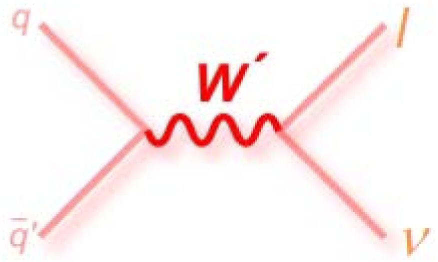
Z'_ψ to ee



Z' mass (TeV/c²)

Lepton - Neutrino

- Heavy charged bosons able to decay into lepton + neutrino
- Use transverse mass



$$m_T = \sqrt{2 p_T \not{E}_T (1 - cos\Delta\phi_{\ell, \not{E}_T})}$$

After rejecting events with high jet activity, the main remaining Backgrounds are from:

- tail of the SM W boson
- Misreconstructed leptons

W' Selection

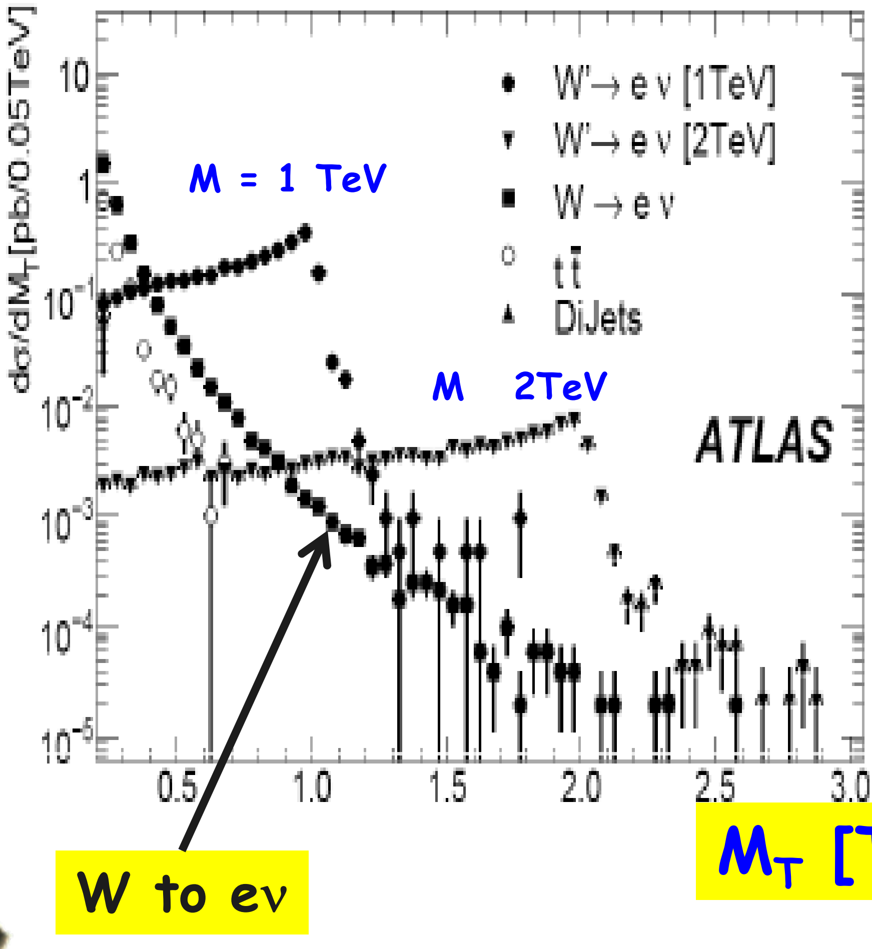
- ATLAS: one lepton with pT > 50 GeV and |eta|<2.5; E_T^{Miss}> 50 GeV
- CMS: one lepton with pT > 30 GeV and |eta|<2.5;
  0.4< p_T/E_T^{Miss} < 1.5 and $\Delta\phi$ cut

- Irreducible background: W to lν
- Reducible background: ttbar and jets
- Further background rejection: isolation; jet-veto

W' Selection

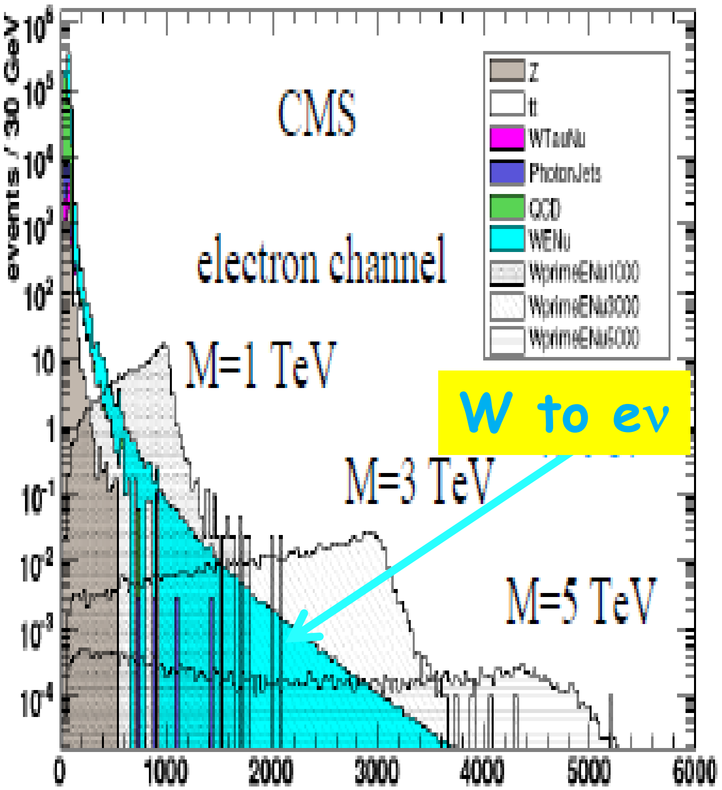
Electron Channel

ATLAS



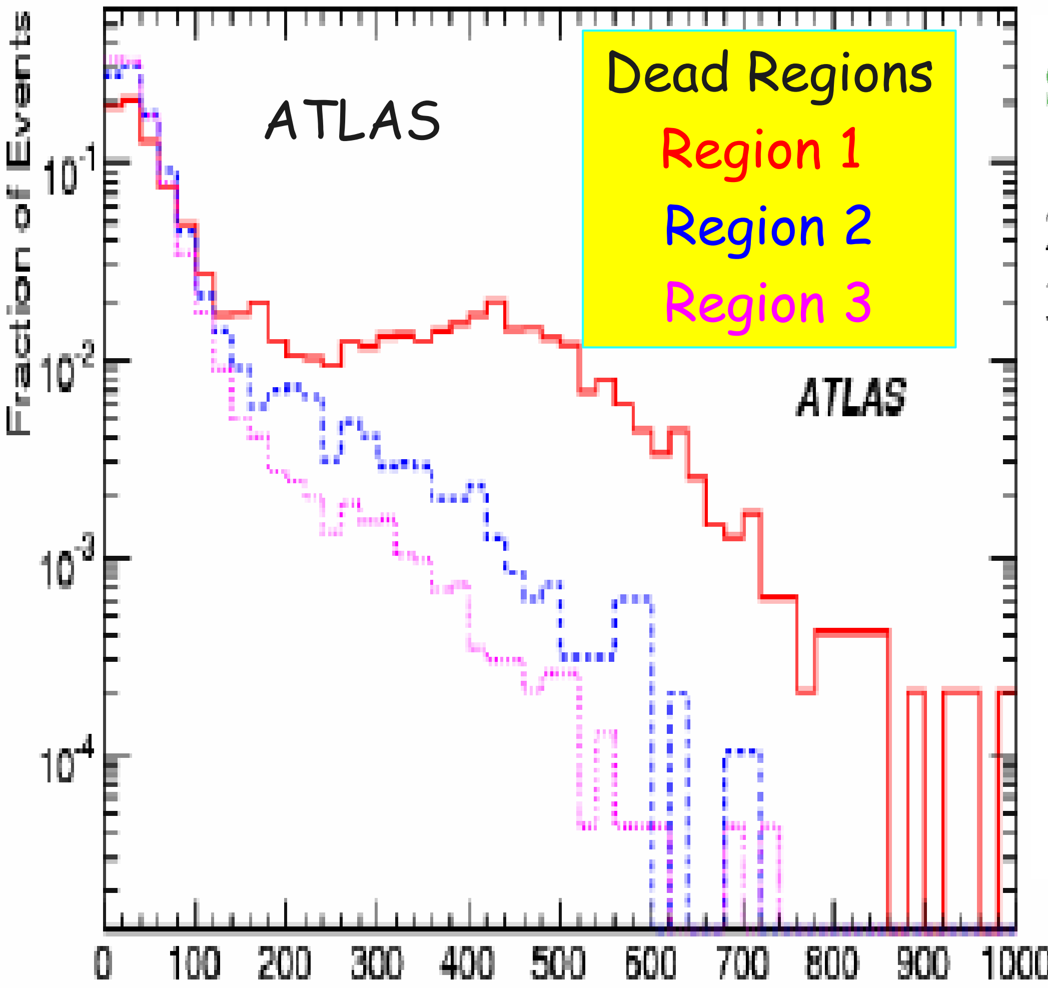
M_T [TeV]

CMS Preliminary



M_T [GeV]

W' - Fake E_T^{Miss}



E_T^{miss} (GeV)

Several sources of fake E_T^{Miss}:

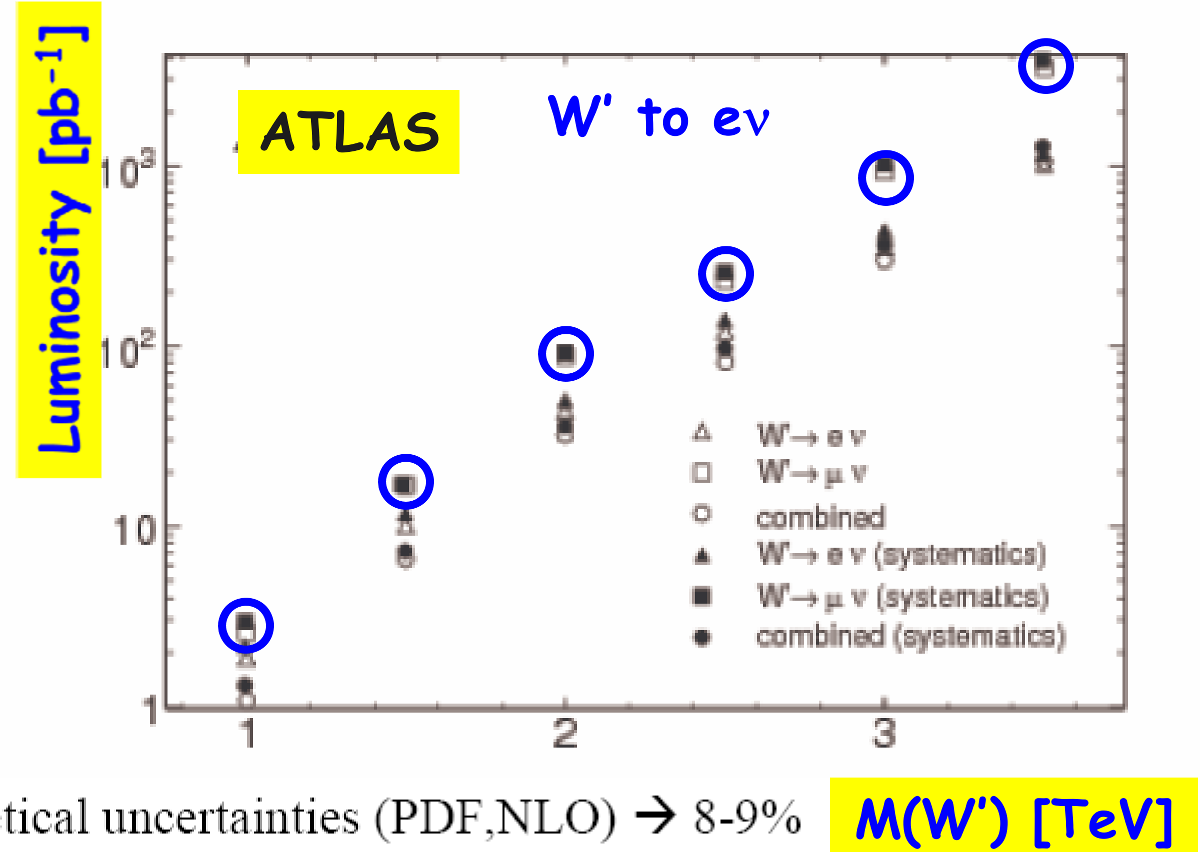
1. Not reconstructed muons
2. Cracks and gaps in calorimeters
3. Instrumental effects (crucial in first data taking)

Region 1: two dead LArEM regions
one dead HEC region

Region 2: one dead LArEM region
one dead HEC region

Region 3: No dead regions

W' Discovery Potential: ATLAS



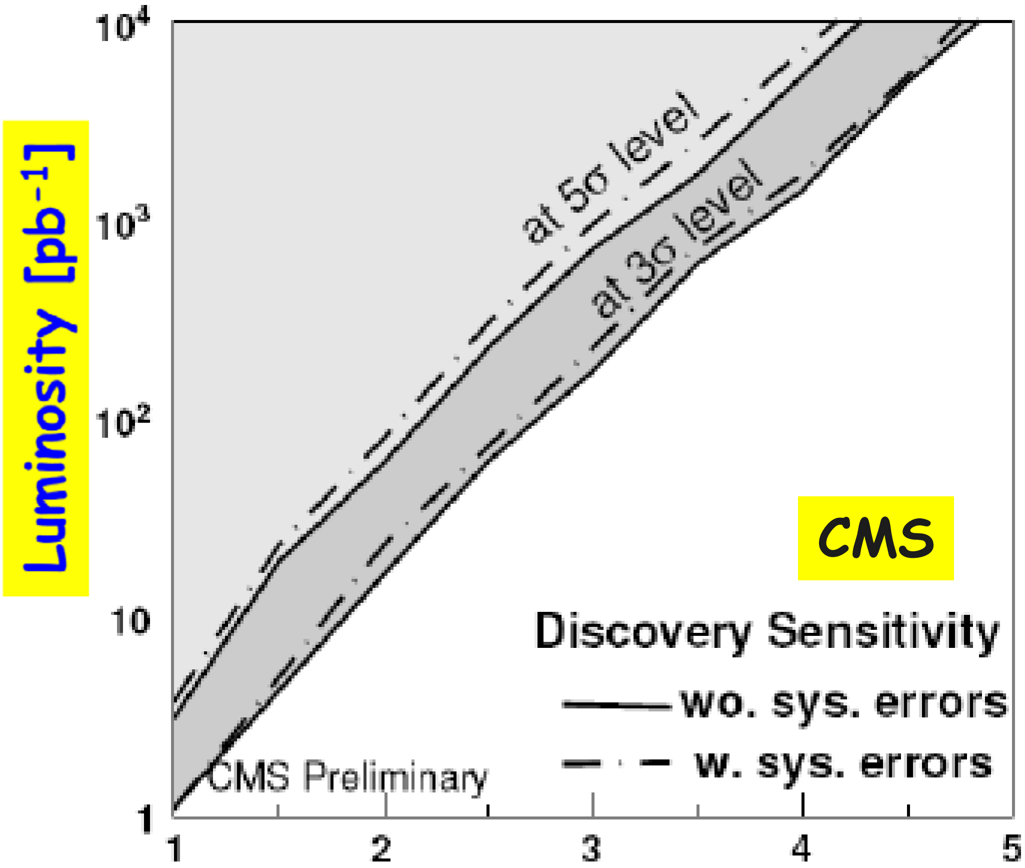
Theoretical uncertainties (PDF,NLO) → 8-9%

Experimental uncertainties (Atlas):

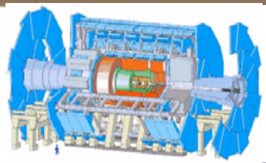
1. signal → 1.5% (electrons), 5% (muons)
2. background → 3% (electrons), 8% (muons)

Discovery in the TeV region with O(10 pb^{-1})

W' Discovery Potential: CMS



@10 TeV: few tens of pb^{-1} are needed to obtain discovery potential just beyond the Tevatron limit



Leptons + Jets

Leptoquarks:

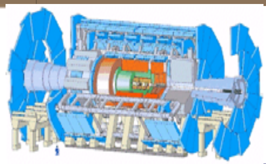
- Lepton-quark symmetry
- Study: Scalar LQ

$$LQLQ \rightarrow l^{+}ql^{-}q$$

- 2 jets + 2 leptons: 1^{st} and 2^{nd} generations
- No missing energy

W_R boson

- Predicted in LRSM
- decay into a lepton and right-handed Majorana Neutrino
- two leptons and two jets in the final state
- No missing energy



Lepton + Jets Selection

- Two isolated e or mu with pT > 20 GeV, |eta|<2.5
- Leptons invariant mass above Z mass
- two jets with pT > 20 GeV and |eta|<4.5

Main Background

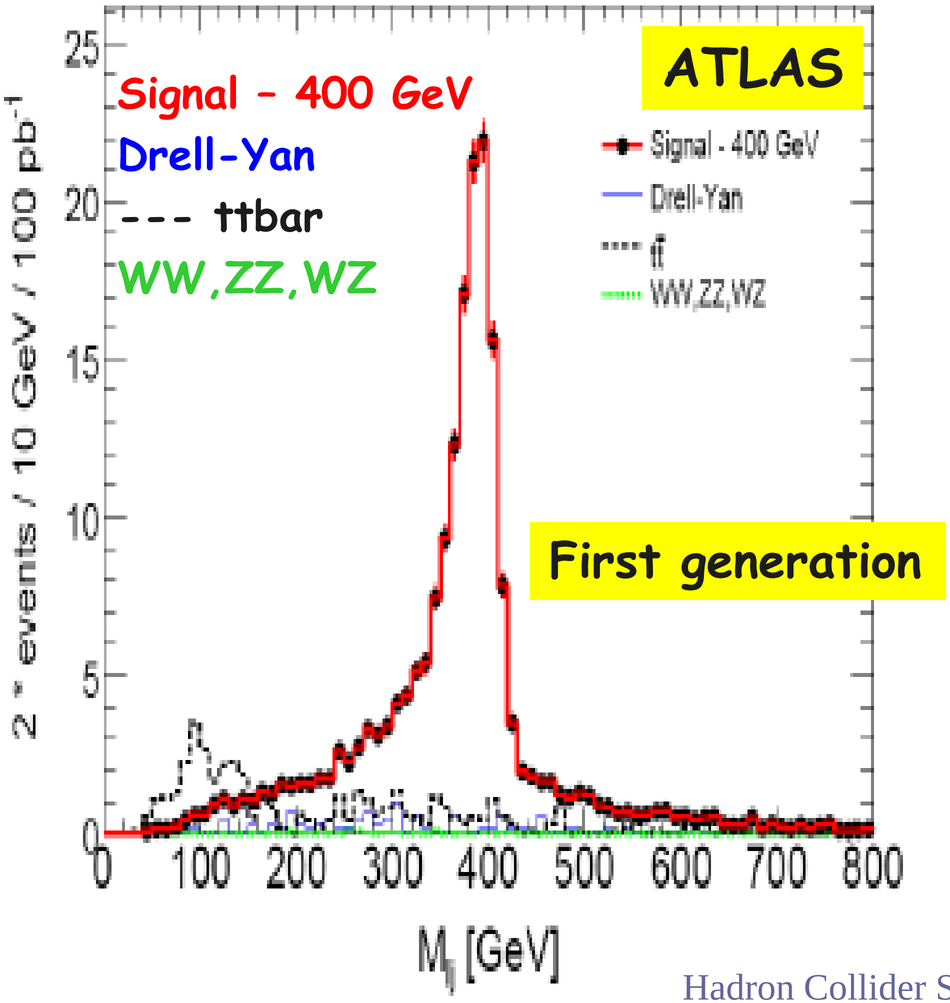
- Top pairs
- DY with two more jets

Additional backgrounds

- Vector boson pairs
- Multijets (with fake leptons)

Lepto Quarks

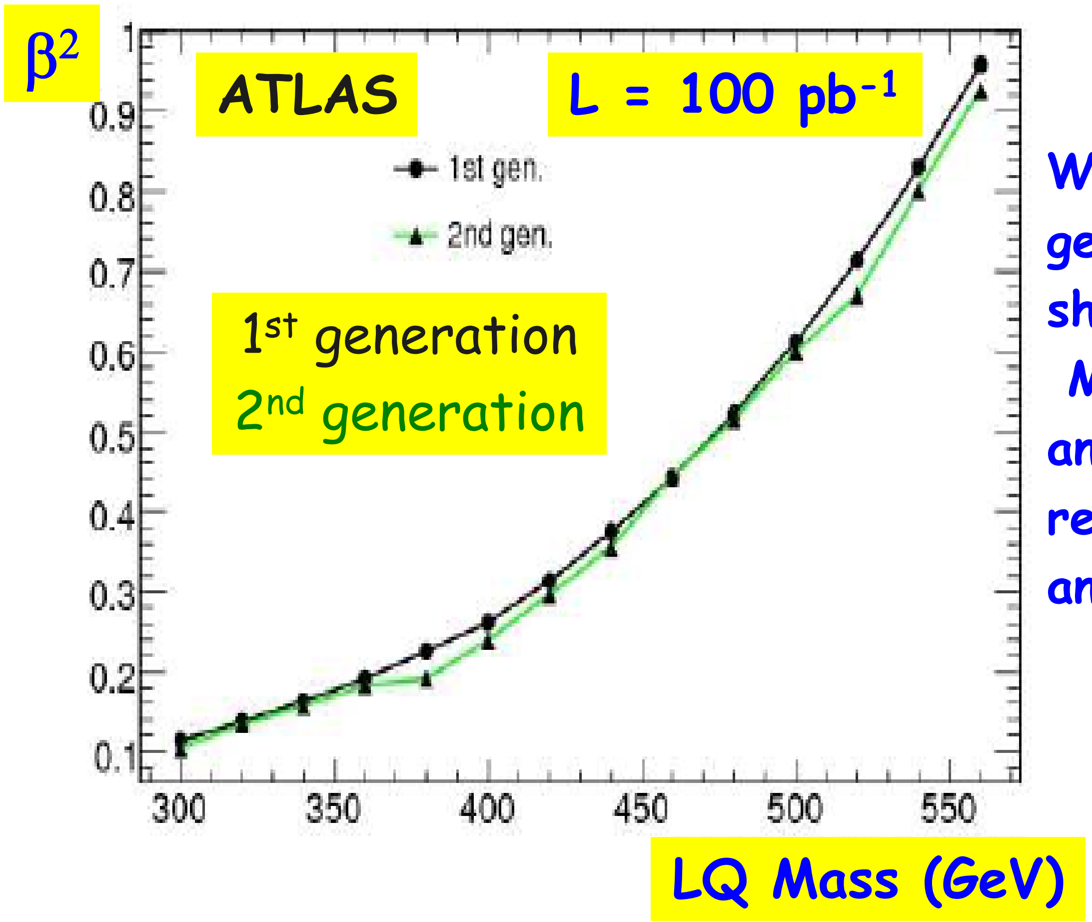
100 pb^{-1}



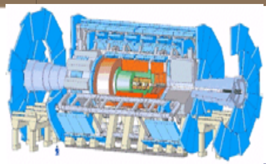
- two leptons with opposite sign and same flavor
- at least two jets
- di-leptons invariant mass
- lepton-jet invariant mass
- $S_T = \sum |\vec{p}_T|_{jet} + \sum |\vec{p}_T|_{lep}$

Sensitivity

@ 14 TeV



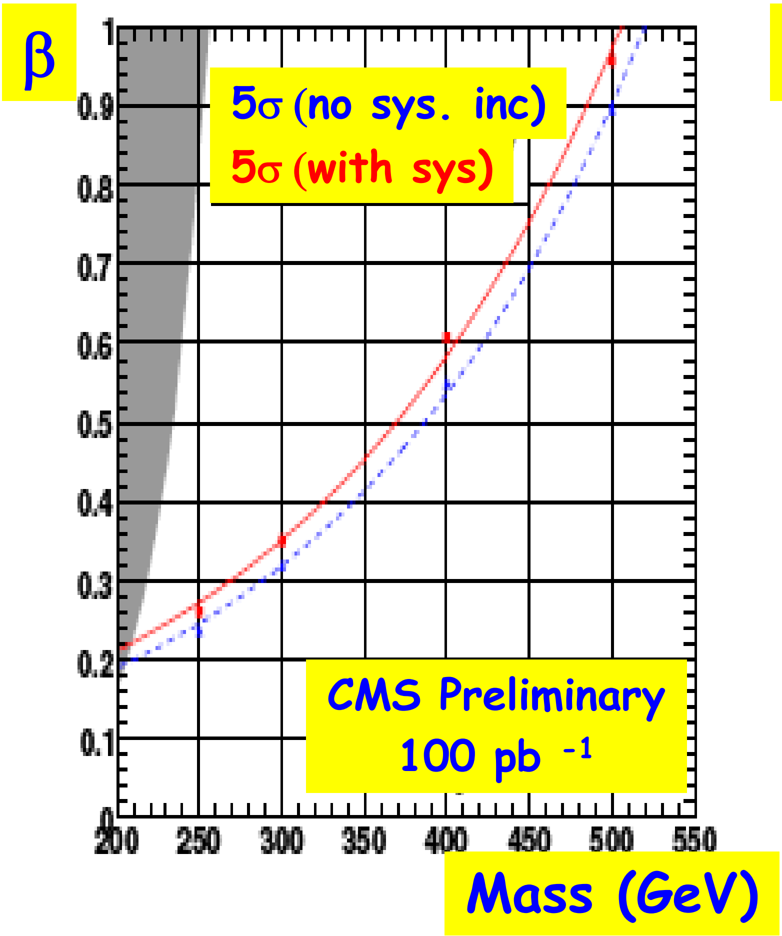
With 100 pb^{-1}, 1st generation LQ discovery should be possible up to a M_{LQ} of about 560, 380, and 300 GeV, assuming, respectively, β= 1, 0.5 and 0.3



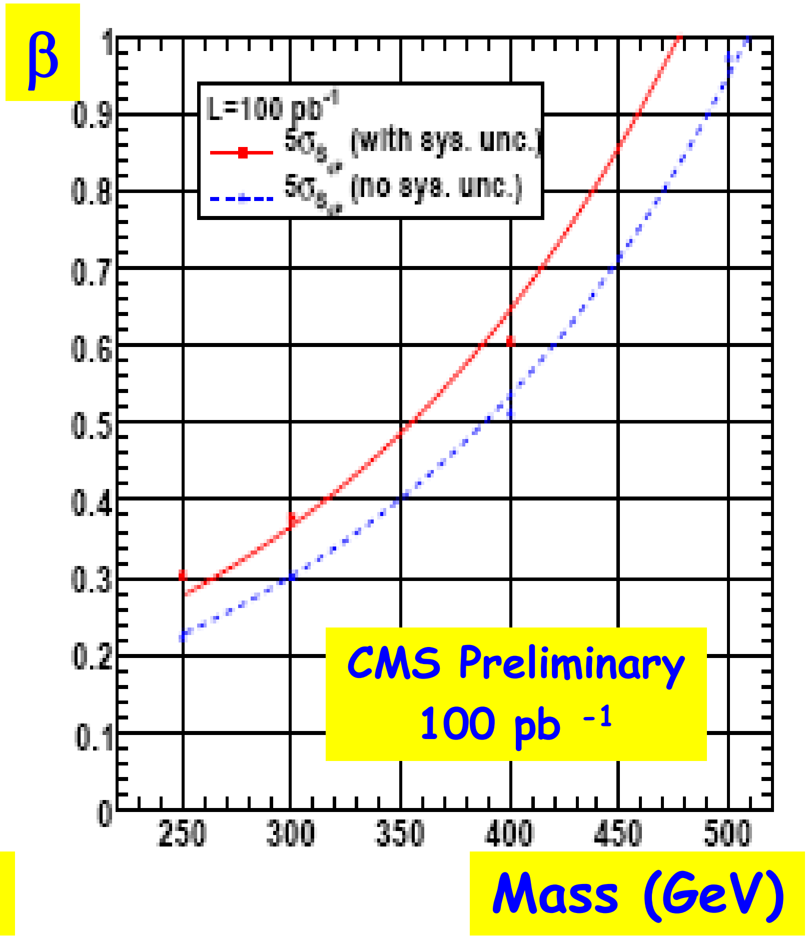
Sensitivity

@ 10 TeV

First Generation LQ

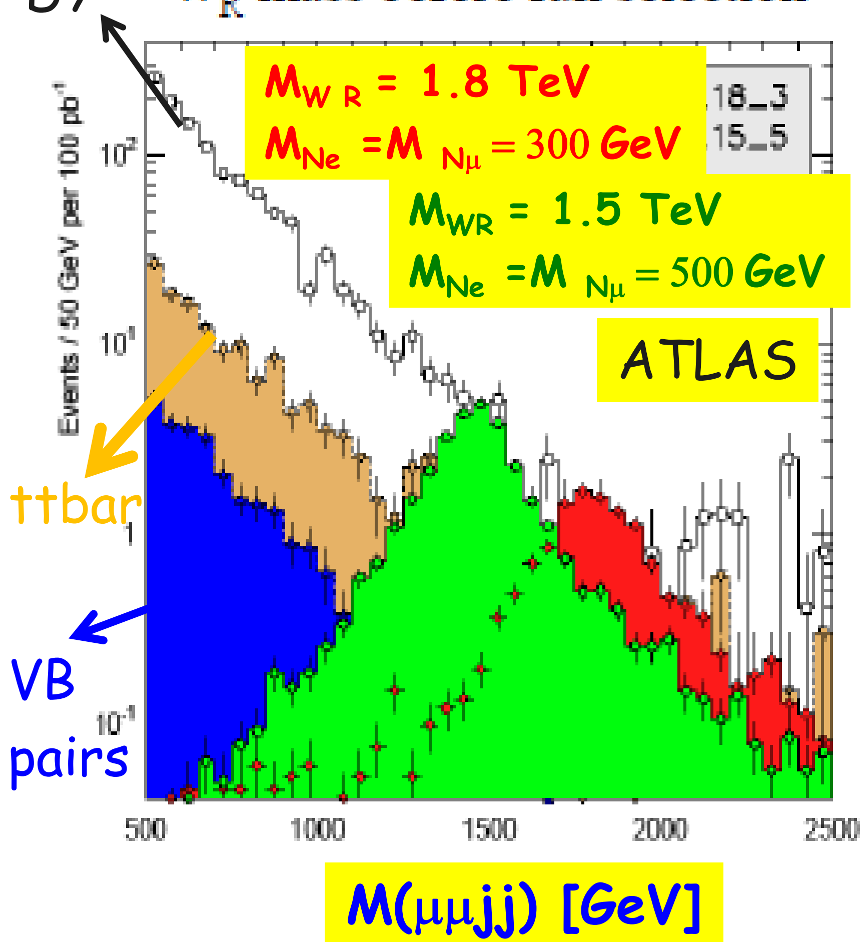


Second Generation LQ

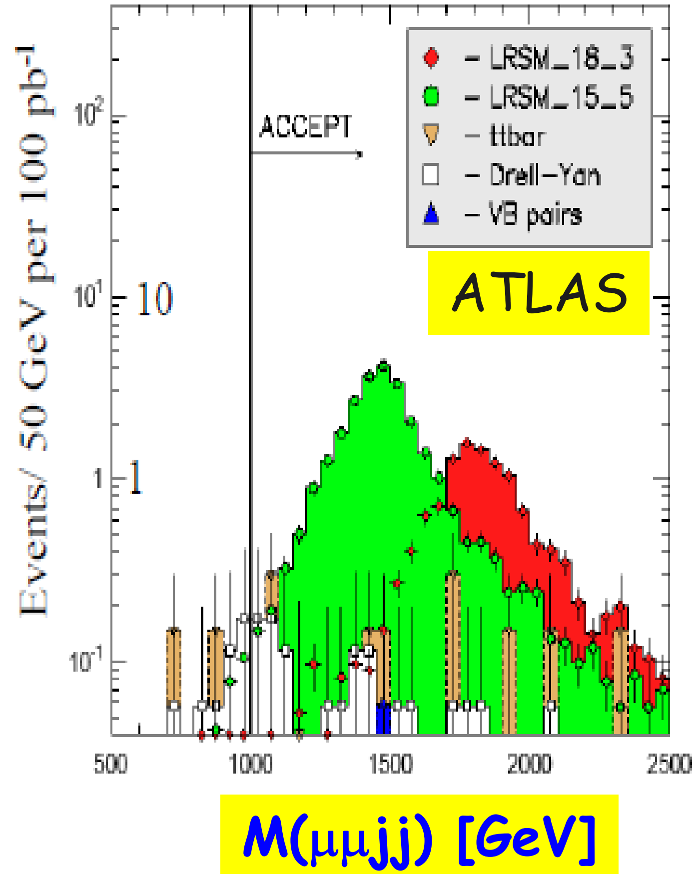


W_R

W$_R$ mass before full selection

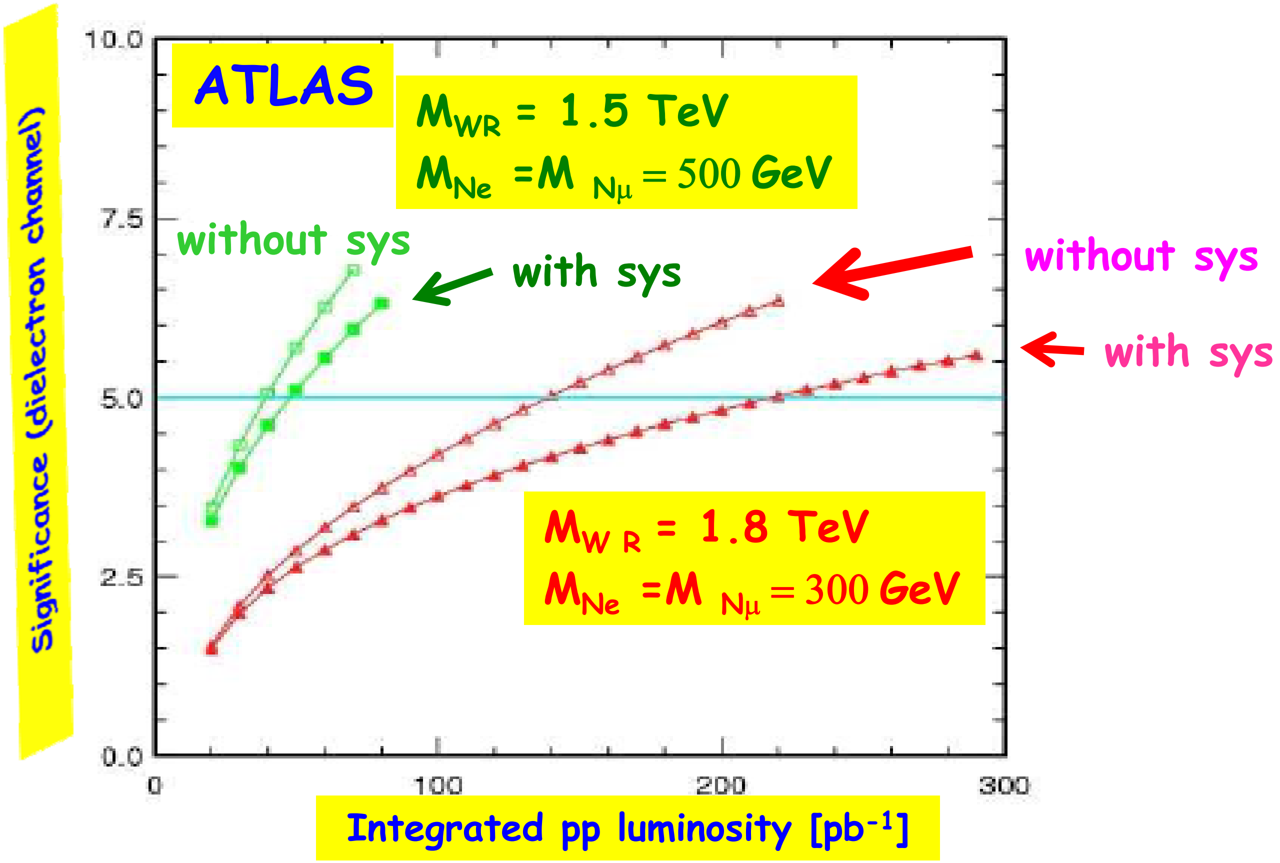


W$_R$ mass after selection



Similar results for electron channel

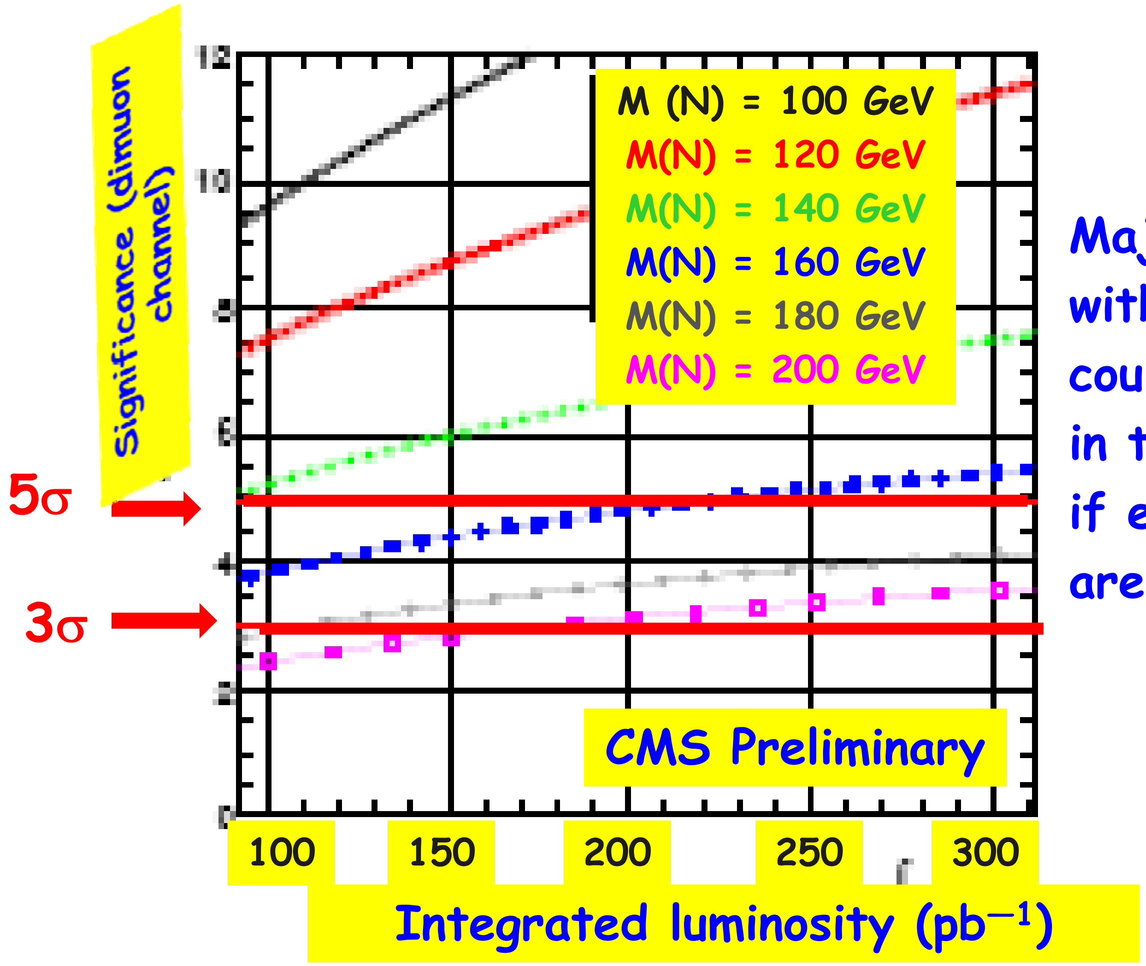
Sensitivity



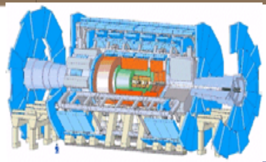
5σ discovery is possible with $O(100\ pb^{-1})$

@10 TeV, signal and backgrounds are a factor 2-3 smaller

Sensitivity: 10 TeV



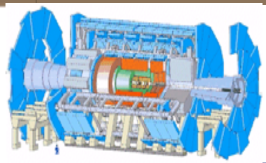
Majorana neutrino with mass < 200 GeV could be observed in the early data, if excess events are seen



Conclusions

Early collisions data

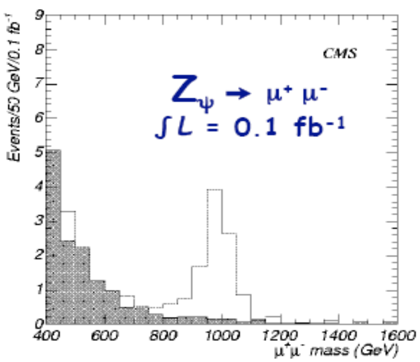
- With good understanding of the detectors performance in situ in the LHC environment, we will be able to explore energy regime beyond that of the Tevatron with low integrated luminosities.
- Many analyses can set world's best limits with less than 100 pb^{-1} (200 pb^{-1} at 8 TeV) of well understood data
- We need credible and defensible systematics for high pt objects, but don't need to be small



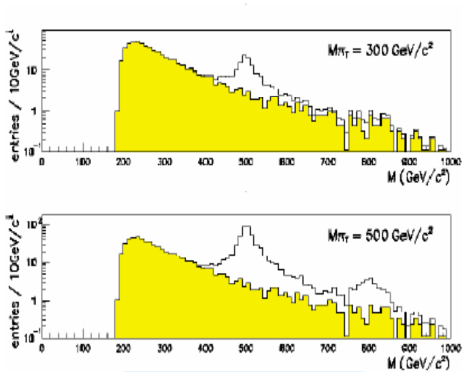
With more time and more data

LHC will explore the TeV scale in detail with direct discovery potential up to m ~ 5-6 TeV

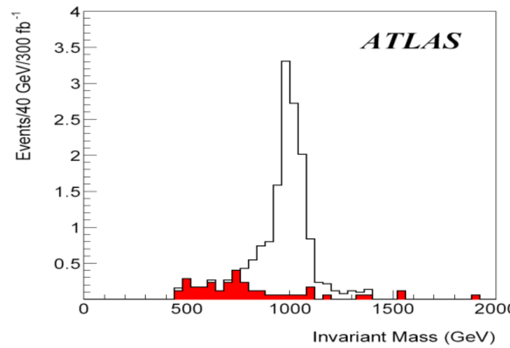
New Gauge Bosons?



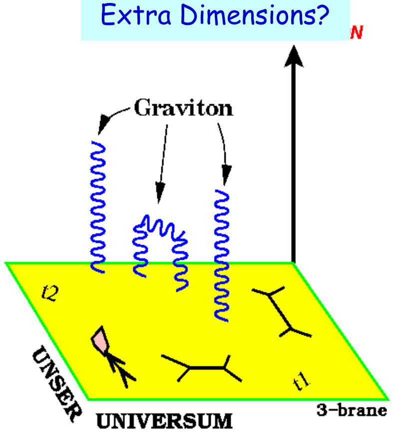
Technicolor?



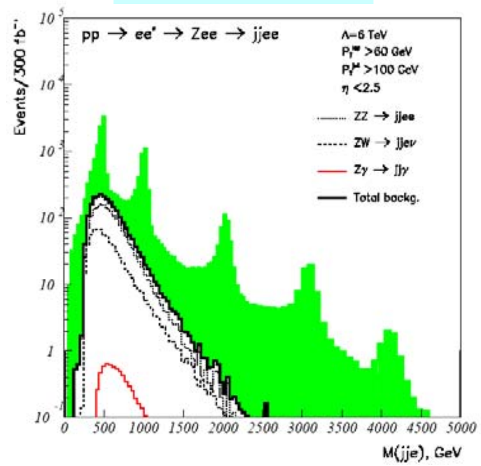
Little Higgs?



Extra Dimensions?



Exited electrons?



Black Holes???

References

ATLAS

CERN-OPEN-2008-020 "Expected Performance of the ATLAS Experiment. Detector, Trigger and Physics"

2008 JINST 3 S08003 "The ATLAS Experiment at the CERN Large Hadron Collider"

CMS

CMS PAS SBM-07-002 "Search for New High-Mass Resonances Decaying to Muon Pairs in the CMS Experiment"

CMS PAS EXO-08-001 "Search for high mass resonance production decaying into an electron pair in the CMS experiment"

CMS PAS EXO-09-006 "Search for high mass resonance production decaying into an electron pair in CMS at 10 TeV with 100 pb^{-1}"

CMS PAS EXO-08-004 "Discovery Potential of $W' \rightarrow e\nu$ at CMS"

2008 JINST 3 S08004 "The CMS Experiment at the CERN LHC"

Backup Slides